~~First, consider the benefit of overlapping power pistons on the power stroke e.g., a 2-stroke, 6 cyl engine with a 9" piston stroke would simultaneously have the 1st piston 6" after tdc, the 2nd piston 3" after tdc and the 3rd piston igniting at tdc. The 6 pistons continuously cycle through their power strokes in this sequence. The power added by the 3rd piston is reduced by the combined remaining power of the 1st and 2nd pistons resulting in fuel savings and smooth power shaft rotation.~~

~~Underlying Mathematics.~~

~~Definitions:~~

~~**1 BTU** = 778 ft-lbf~~

~~1 hp = 550 ft-lbf/sec~~

~~$2\pi r'$ = length of 1-way clutch rim at connecting rod contact. (ft).~~

~~**bore** – cylinder diameter. (in.)~~

~~**Cp** - cylinder pressure calculated from know bore size. (psi)~~

~~**F** – combustion force perpiston (lbf)~~

~~**F′** – estimated combustion pressure per piston. Used to find bore size. (psi)~~

~~**Fr** – fuel flow rate (lbm/sec.)~~

~~**hp** – shaft horsepower~~

~~**k** = 2 or 4 (k = 2 for a 2-stroke. k = 4 for a 4-stroke.)~~

~~**Lo** – Power losses (fraction of hp)~~

~~**n** – number of active pistons. 2,4,6, 8, ...~~

~~**n/k** – number of overlapping pistons cycling through the power stroke.~~

~~**Qc** – fuel's energy density. (BTU/lbm).~~

~~**r′** – 1-way clutch radius at connecting rod contact. (ft)~~

~~**r** – radius of cylinder. (in)~~

~~**Rv** – power shaft's rotation rate. (rpm)~~

~~**Sp** – shaft power + losses. (ft-lbf/sec.)~~

~~**T** – Torque per piston. (lbf-ft)~~

~~**T′** - total shaft torque. (lbf-ft)~~

~~**Vp** – piston's velocity. (ft/sec)~~

~~Equations:~~

~~$Vp = (\pi)(r')(Rv)/(30)$ Piston's speed and the 1-way clutch rim speed are equal at contact..~~

~~$r' = 30(Vp)/\pi(Rv)$ r′,Vp,Rv are central to this engine's design and operation..~~

~~$Rv = 30(Vp)/\pi r'$~~

~~$F = 550hp(k)/(nVp)$~~

~~$F = 16500(hp)(k)/\pi(n)(Rv)(r')$~~

~~$T = F(r')$~~

~~$T' = nT/k$~~

~~$F' = F/[(\pi r_b^2)]$~~

~~$r^2 = F/(\pi F')$~~

~~$bore = 2[F/(\pi F')]^{.5}$~~

~~$Cp = 4F/(\pi bore^2)$~~

~~$F = \pi F'(bore^2)$~~

~~$Sp = 550hp(1+Lo)$~~

~~$Fr = (Sp)/(778Qe)$~~

~~$Fr = (F)(n)(Vp)/[k(778Qe)]$~~

~~Examples that find preliminary information to any size engine with a hand calculator. (800 psi is estimated where used.)~~

~~Example: 6 cylinder, 2 stroke 700 hp.~~

~~1. Let: **hp** = 700; **Vp** = 15 ft/sec; **F′** = 800 psi; **n** = 6; **k** = 2; **r′** = .75 ft = 9 in.~~

~~**F** = 2(700)(550)/6(15) = 8556 lbf.~~

~~**Rv** = 30(15)/(.75π) = **191** rpm~~

~~**bore** = $2(8556/800\pi)^{.5}$ = 3.690 in.~~

~~**T**. = 8556(.75) = 6417 lbf-ft~~

~~**T′** = 6(6417)/(2) = 19251 lbf-ft.~~

~~Example: 6 cylinder, 2 stroke, 1200 hp.~~

~~2. Let: **hp** = 1200; **Vp** = 22 ft/sec; **n** = 6; **k** = 2; **r′** = .75 ft. = 9 in. (Compare results to 1.)~~

~~**F** = 2(1200)(550)/[(6)(2)] = 10000 lbf.~~

~~**Rv** = 30(22)/(.75π) = 280 rpm~~

~~**bore** = 3.690 in. (from example 1.)~~

~~**Cp** = $4(10000)/[\pi(3.690^2)]$ = 935 psi. (Compare to **F′** = 800 psi in 1.)~~

~~**T** = 10000(.75) = 7500 lbf-ft~~

~~**T′** = 6(7500)/2. = 22500 lbf-ft~~

~~Example: 8 cylinder, 4-stroke (2 banks of 4 cyls. each) 1200 hp engine. See FIG 6.~~

~~3. Let: **hp** = 1200; **F′** = 800 psi; **n** = 8; **k** = 4; **Rv** = 115 rpm; **r′** = 1.25 ft. (1 cyl. per 1-way clutch requiring eight 1-way clutches. 50% overlap.)~~

~~**Vp** = 1.25π(115)/30 = 15.05 ft/sec.~~
~~**F** = 4(550)(1200)/[(8)(15.05)] = 21927 lbf.~~
~~**bore** = $2(21927/800\pi)^{.5}$ = 5.907 in. (Compare to example 3.)~~

~~$T = 21927(1.25) = 27409$ lbf-ft.~~

~~$T' = 8(27409)/4 = 54818$ lbf-ft.~~

~~Example: 4 cylinder, 4-stroke 200 hp automobile engine. See FIG 6.~~

~~4. Let: **hp** = 200; **F′** = 800 psi; **n** = 4; **k** = 4; **Vp** = 15 ft/sec; **r′** = .5 ft. = 6 in. (2 cyl. per 1-way clutch requiring eight 2-way clutches. No power stroke overlap.)~~

~~**F** = 4(550)(200)/[(4)(15)] = 7333 lbf.~~

~~**Rv** = 30(15)/(.5π) = 286 rpm.~~

~~**bore** = $2(7333/800\pi)^{.5} = 3.416$ in.~~

~~**T** = 7333(.5) = 3667 lbf-ft.~~

~~**T′** = 4(7333)/4 = 7333 lbf-ft.~~

~~Example: 8 cylinder, 2-stroke, 8,000 hp large marine engine.~~

~~5. Let: **hp** = 8000; **F′** = 800 psi; **n** = 8; **k** = 2; **Vp** = 28 ft/sec; **Rv** = 120 rpm. (1 cyl. per 1-way clutch requiring eight 1-way clutches. 14" piston stroke. 75% power stroke overlap.)~~

~~**F** = 2(550)(8000)/[(8)(28)] = 39286 lbf.~~

~~**r′** = 30(28)/(120π) = 2.228 ft. The transmitting units 89 (FIGs 7,8) could be carried by a short outer race 5 with a single spoke 35 to reduce inertia.~~

~~**bore** = $2[(39286/800\pi)]^{.5} = 7.907$ in.~~

~~**T** = 39286(2.228) = 87529 lbf-ft.~~

~~**T′** = 8(39286)/2 = 157144 lbf-ft.~~

~~Next, comparing the number of cylinders in this smaller engine to the number of cylinders in an equal powered crank engine.~~

~~1. For a 2-stroke engine with **n** cyls., let **n** = 6 then $\mathbf{n}^2/2$ = 18 crank engine cyls.~~

~~2. For a 4-stroke engine with **n** cyls., let **n** = 8 (two banks of 4 pistons each in FIG 6),~~

~~then $\mathbf{n}^2/4$ = 16 crank engine cyls.~~

~~**Discussion.**~~

~~A pair of combustion cylinders 33 and related pairs of parts that include a pair of 1-way clutches (FIGs 1-3) make the basic 2-stroke engine in this invention. The clutch's inner race 4 is keyed to the power shaft 8. The outer race 5 carries a sector gear 12. Each gear 12 engages an opposite side of idler 40 whereby synchronous reverse motion is transmitted between the power piston 38 and the second piston 38 in the pair as the inner race 4 transmits the power to the shaft 8. Moving parts that are not shown with arrows 42 are presumed obvious.~~

~~Combining two pairs with idler 40A creates a 4-stroke shown in FIG 6 that will be described later under Interchanging 4-stroke and 2-stroke.~~

~~FIG 2 shows a gear mesh to transmit the piston's power between piston rod 18 and the outer race 5 of the 1-way clutch. Rod 18 reciprocates along a straight path 42. FIG 2 also shows a reciprocating starter 46 gear meshed with the outer race 5. By shifting race 5, the starter shifts both pistons 38 until ignition. Alternatively, shaft 43 can be used to shift the pistons until ignition. The 4-stroke version in FIG 6 needs one starter 46 (not shown).~~

~~One end of a V-belt or a chain 9 is fastened to the outer race 5 (FIGs 1,3). The way it is wrapped around race 5 always keeps it taut, which prevents backlash as it rotates race 5 in response to the power stroke. Rod 18 is connected to the other end of the belt or chain 9 with a suitable fastener 41.~~

~~The 1-way clutch's override feature in this engine allows output shaft 8 and the clutch's inner race 4 to rotate independently of the pistons 38 when the inner race's speed is greater than the outer race 5 speed. This feature creates regenerated energy is collection in an energy storage device 26 (FIG 5) available, e.g. for dumping to shaft 8 on demand or generating electricity.~~

~~The fixed length torque arm 10 (FIGs 2,3) causes instant peak torque at the beginning of the power stroke. A connecting rod guide 21, secured to housing 15, eliminates side thrust and reduces wear by keeping the piston 38 square in its cylinder. Wrist pins and piston skirts are not needed. The guide 21 is combined with a decelerator mechanism (FIG 4) to stop piston 38 at or near top dead center. The decelerator includes a node 19 that is part of each rod 18 in a pair and a spring 45 for each node. The spring is encased in the guide 21. An opening in the housing 15 allows easy replacement of the spring. The spring absorbs the impact of node 19 to halt the motion of piston 38, which is then accelerated on its power stroke by timely expanding combustion gases. The impact is reduced because node 19 is decelerating due to the power loss of the power piston to the shaft 8. The decelerator is positioned to prevent backlash of the gears 12 (FIGs 1,6) that mesh with idler 40.~~

~~A computer 7 (FIG 5) monitors input from the throttle 6 and shaft power from the sensor 22 on shaft 8 through leads 23 to determine the size of the combustion charge (**Fr** = (Sp)/(778)Qc)lbm/sec) to transmit to the cylinders through injector lines 24. The position of piston 38 is monitored through sensors 22 on shaft 43 and used for ignition timing. By monitoring the motion of each shaft 43 in several pairs, the computer controls timing between the unconnected pairs in a 2-stroke embodiment. The computer begins a power stroke with a piston in one pair when a piston in another pair is partly through its power stroke. In a 2-stroke, 50% power stroke overlap and smooth rotation of the shaft 8 is had with two unconnected pairs (four cylinders). Greater overlap is gained with more pairs.~~

~~Small Flywheels.~~

~~Load changes on shaft 8 could decrease **F** lbf below what is needed for an efficient combustion pressure. A small, suitable flywheel 48 is splined to the end of shaft 43 (FIG 3) to briefly increase chamber pressure for a more complete combustion with decreased emissions. Then, it dispenses the regenerated energy that it gains to moderate the speed of the pistons 38. A conventional flywheel can be used but an alternative comprises three concentric parts. The inner part is splined to shaft 43. The outer part extends to the flywheel's rim. Between them is a tough, slightly elastic part that absorbs some of the initial ignition jolt.~~

First, consider the benefit of overlapping power pistons on the power stroke controlled by the engine computer 7 (FIG 5). For example, a 2-stroke, 6 cyl engine with a 9" piston stroke would have the 1st piston 6" after tdc, the 2nd piston 3" after tdc and the 3rd piston igniting at tdc. The 6 pistons continuously cycle through their power strokes in that sequence. The power added by the 3rd piston is reduced by the combined remaining power of the 1st and 2nd pistons resulting in fuel savings and smooth power shaft rotation.

Underlying Mathematics.

Definitions

1 BTU = 778 ft-lbf.

1 hp = 550 ft-lbf/sec.

2πr′ = length of 1-way clutch rim at connecting rod contact. (ft)

bore – cylinder diameter. (in.)

Cp – cylinder pressure calculated from known bore size. (psi)

Dp – displacement. (cu.in.)

E – engine efficiency.

F – combustion force per piston. (lbf)

F′ – estimated combustion pressure per piston. (psi) Used to find the bore size. (in.)

Fg – fuel flow rate. (gals/hr)

Fr – fuel flow rate. (lbm/sec)

Fw – fuel's weight. (lbm/gal.)

hp – shaft horsepower.

k = 2 or 4 (k = 2 for a 2-stroke. k = 4 for a 4-stroke.)

Lo = total efficiency – engine efficiency. (0.0 < Lo < 1.0)

n – number of active pistons. 2,4,6,8, ...

n/k – number of overlapping pistons simultaneously cycling through the power stroke.

Ps – length of piston's stroke. (in.)

Qc – fuel's energy density. (BTU/lbm)

r – radius of cylinder. (in)

r′ – 1-way clutch radius at connecting rod contact. (ft)

Rv – power shaft's rotation rate. (rpm)

T – torque per piston. (lbf-ft)

T′ – total shaft torque. (lbf-ft)

Vp – piston velocity. (ft/sec)

Equations:

$Vp = \pi(r')(Rv)/(30)$ Piston rod's and the 1-way clutch's rim speeds are equal at contact.

$r' = 30(Vp)/\pi(Rv)$ **r', Vp, Rv** are central to this engine's design and operation.

$Rv = 30(Vp)/(\pi r')$

$F = 550hp(k)/(nVp)$

$T = F(r')$

$T' = nT/k$

$F' = F/[\pi(r^2)]$

$r^2 = F/(\pi F')$

$bore = 2[F/(\pi F')]^{.5}$

$F = \pi F'(bore^2)/4$

$Cp = 4F/(\pi bore^2)$

$Dp = \pi(Ps)(n)(bore/2)^2$

$Fr = 550hp/[778(Qc)(1-Lo)]$

$Lo = 1 - 550hp/778(Qc)(Fr)$

$E = 1 - Lo$

$E = 550hp/778(Qc)(Fr)$

$Fg = Fr(3600)/(Fw)$

The examples next are only to illustrate how the underlying mathematics can be used to find basic engine specifications. Input values are estimates.

Examples:

1. A 2 cylinder, 2-stroke, 45 hp engine.

Let: **hp** = 20; **k** =2; **n** = 2; **F′** = 575 psi; **r′** = .5 ft; **F** = 1100 lbf; **Ps** = 4.5 in;

Fw = 6 lb/gal; **Qc** = 20500; **Lo** = .35

Vp = 10 ft/sec = $550(20)(2)/(2)(1100)$

bore = 1.561 in. = $2(1100/575\pi)^{.5}$ Set bore size at most frequently used 20 hp.

Rv = 191 rpm. = $30(10)/(.5\pi)$ Reduction gear may be required.

Dp = 17.2 cu.in. = $\pi(1.561/2)^2(4.5)(2)$

Fr = .001061074 lbm/sec. = $550(20)/(778)(20500)(1-.35)$

Fg = .6367 gals/hr. = $.001061074(3600)/6$

T = 550 lbf-ft. = 1100(.5)

Let: **hp** = 45; **k** =2; **n** = 2; **F′** = 575 psi; **r′** = .5 ft; **Vp** = 15 ft/sec.

bore = 1.561 in. = $2(1100/575\pi)^{.5}$ bore size same as 20 hp.

F = 1650 lbf. = 550(45)(2)/(2)(15)

Rv = 286 rpm. = $30(15)/(.5\pi)$ Reduction gear probably required.

Cp = 862 psi. = $4(1650)/\pi(1.561^2)$

Fr = .002387418 lbm/sec. = 550(45)/(778)(20500)(1-.35)

Fg = 1.432 gals/hr. = . 002387418(3600)/6

T = 825 lbf-ft. = 1650(.5)

2. A 4 cylinder, 4-stroke 400 hp engine.

Let: **hp** = 50; **Vp** = 14 ft/sec; **F′** = 700 psi; **n** = 4; **k** = 4; **r′** = .75 ft = 9 in.; **Ps** = 5.0 in;

Fw = 6 lb/gal; **Qc** = 20500; **Lo** = .35

F = 1964 lbf. = 4(50)(550)/4(14)

Rv = 178 rpm = $30(14)/(.75\pi)$

bore = 1.890 in. = $2(1964/700\pi)^{.5}$ Set bore size at most frequently used 50 hp.

Dp = 56 cu.in. = $\pi(1.890/2)^2(5.0)(4)$

Fr = .002652686 lbm/sec. = 550(50)/(778)(20500)(1-.35)

Fg = 1.592 gals/hr. = .002652686(3600)/6

T = T′ = 1473 lbf-ft. = 1964(.75)

Let: **hp** = 400; **Vp** = 27 ft/sec; **F′** = 800 psi; **n** = 4; **k** = 4; **r′** = .75 ft = 9 in.

F = 8148 lbf. = 4(400)(550)/4(27)

Rv = 344 rpm = $30(27)/(.75\pi)$

bore = 1.890 in. bore size same as 50 hp.

Cp = 2904 psi. = $4(8148)/\pi(1.890^2)$

Fr = .02122149 lbm/sec. = 550(400)/(778)(20500)(1-.35)

Fg = 12.733 gals/hr. = . 02122149(3600)/6

T = T′ = 6111 lbf-ft. = 8148(.75)

* If this engine were a 2-Stroke, there could be 50% power stroke overlap with both pairs active.
At low power, a pair of pistons could be stopped without load on the engine.

3. A 6 cylinder, 2-stroke 1200 hp. engine.

~~Let: **hp** = 700; **Vp** = 25 ft/sec; **F′** = 800 psi; **n** = 6; **k** = 2; **r′** = .75 ft = 9 in; **Ps** = 6.0 in.~~

F = 5133 lbf. = 2(700)(550)/6(25)

Rv = 318 rpm = 30(25)/(.75π)

bore = 2.858 in. = $2(5133/800\pi)^{.5}$ Set bore size to most frequently used power.

Dp = 231 cu.in. = $\pi(2.858/2)^2(6.0)(6)$

T = 3850 lbf-ft. = 5133(.75)

T′ = 1150 lbf-ft. = 6(3850)/(2)

Let: **hp** = 1200; **Vp** = 35 ft/sec; **n** = 6; **k** = 2; **r′** = .75 ft. = 9 in.

F = 6285 lbf. = 2(1200)(550)/[(6)(35)]

Rv = 446 rpm = 30(35)/(.75π)

~~**bore = 2.858 in.** bore size same as 700 hp.~~

Cp = 980 psi. = $4(6285)/\pi(2.858^2)$

T = 4714 lbf-ft. = 6285(.75)

T′ = 1414 lbf-ft. = 6(4714)/2

4. An 8 cylinder (2 banks of 4 cyls. each), 4-stroke, 1200 hp engine.

Let: **hp** = 1200; **F′** = 800 psi; **n** = 8; **k** = 4; **Vp** = 35 ft/sec; **r′** = 1.25 ft; **Ps** = 6.0 in.

1 cyl. per 1-way clutch requiring eight 1-way clutches. 50% overlap.

Rv = 267 rpm = 30(35)/(1.25π)

F = 9429 lbf. = 4(550)(1200)/[(8)(35)]

bore = 3.874 in. = $2(9429/800\pi)^{.5}$

Dp = 566 cu.in. = $\pi(3.874/2)^2(6)(8)$

T = 11786 lbf-ft. = 9429(1.25)

T′ = 23573 lbf-ft. = 8(11786)/4

5. A large 8 cylinder, 2-stroke, 8,000 hp marine engine.

Let: **hp** = 8000; **F′** = 800 psi; **n** = 8; **k** = 2; **Vp** = 28 ft/sec; **Rv** = 100 rpm; **Ps** = 10 in; **Lo** = .35;

Fw = 7.1 lbm/gal. (1 cyl./1-way clutch uses 8 1-way clutches. 75% power stroke overlap.)

F = 39286 lbf. = 2(550)(8000)/[(8)(28)]

r′ = 2.673 ft. = 30(28)/(100π) Units 89 (FIGs 7,8) are carried by a short rimmed outer race 5

with a single spoke 35 to reduce inertia.

bore = 7.907 in. = $2[(39286/800\pi)]^{.5}$ Set bore size to most frequently used power.

Dp = 3929 cu.in. = $\pi(7.907/2)^2(10)(8)$

Fr = .457600229 lbm/sec. = 550(8000)/(778)(19014)(1-.35)

Fg = 232.02 gals/hr. = .457600229(3600)/7.1

T = 105011 lbf-ft. = 39286(2.673)

T′ = 420046 lbf-ft. = 8(105011)/2

* Reset power by activating/deactivating piston pairs then vary power by varying the fuel charge.

Discussion.

A pair of combustion cylinders 33 and related pairs of parts that include a pair of 1-way clutches (FIGs 1-3) make the basic 2-stroke engine in this invention. The clutch's inner race 4 is keyed to the power shaft 8. The outer race 5 carries a sector gear 12. Each gear 12 engages an opposite side of idler 40 whereby synchronous reverse motion is transmitted between the power piston 38 and the second piston 38 in the pair as the inner race 4 transmits the power to the shaft 8. Moving parts that are not shown with arrows 42 are presumed obvious.

Combining two pairs with idler 40A creates a 4-stroke shown in FIG 6 that will be described later under Interchanging 4-stroke and 2-stroke.

FIG 2 shows a gear mesh to transmit the piston's power between piston rod 18 and the outer race 5 of the 1-way clutch. Rod 18 reciprocates along a straight path 42. FIG 2 also shows a reciprocating starter 46 gear meshed with the outer race 5. By shifting race 5, the starter shifts both pistons 38 until ignition. Alternatively, shaft 43 can be used to shift the pistons until ignition. The 4-stroke version in FIG 6 needs one starter 46 (not shown).

One end of a V-belt or a chain 9 is fastened to the outer race 5 (FIGs 1,3). The way it is wrapped around race 5 always keeps it taut, which prevents backlash as it rotates race 5 in response to the power stroke. Rod 18 is connected to the other end of the belt or chain 9 with a suitable fastener 41.

The 1-way clutch's override feature in this engine allows output shaft 8 and the clutch's inner race 4 to rotate independently of the pistons 38 when the inner race's speed is greater than the outer race 5 speed. This feature creates regenerated energy that is collected in an energy storage device 26 (FIG 5) available, e.g. for dumping to shaft 8 on demand or generating electricity.

The fixed length torque arm 10 (FIGs 2,3) causes instant peak torque at the beginning of the power stroke. A connecting rod guide 21, secured to housing 15, eliminates side thrust and reduces wear by keeping the piston 38 square in its cylinder. Wrist pins and piston skirts are not needed. The guide 21 is combined with a decelerator mechanism (FIG 4) to stop piston 38 at or near top dead

center. The decelerator includes a node 19 that is part of each rod 18 in a pair and a spring 45 for each node. The spring is encased in the guide 21. An opening in the housing 15 allows easy replacement of the spring. The spring absorbs the impact of node 19 to halt the motion of piston 38, which is then accelerated on its power stroke by timely expanding combustion gases. The impact is reduced because node 19 is decelerating due to the power loss of the power piston to the shaft 8. The decelerator is positioned to prevent backlash of the gears 12 (FIGs 1,6) that mesh with idler 40.

A computer 7 (FIG 5) monitors input from the throttle 6 and shaft power from the sensor 22 on shaft 8 through leads 23 to determine the size of the combustion charge to transmit to the cylinders through injector lines 24. The position of piston 38 is monitored through sensors 22 on shaft 43 and used for ignition timing. By monitoring the motion of each shaft 43 in several pairs, the computer controls timing between the unconnected pairs in a 2-stroke embodiment. The computer begins a power stroke with a piston in one pair when a piston in another pair is partly through its power stroke. In a 2-stroke, 50% power stroke overlap and smooth rotation of the shaft 8 is had with two unconnected pairs (four cylinders). Greater overlap is gained with more pairs.

Small Flywheels.

A small, suitable flywheel 48 is splined to the end of shaft 43 (FIG 3) to briefly increase chamber pressure for a more complete combustion with decreased emissions. Then, it dispenses the regenerated energy that it gains to moderate the speed of the pistons 38. A conventional flywheel can be used but an alternative comprises three concentric parts. The inner part is splined to shaft 43. The outer part extends to the flywheel's rim. Between them is a tough, slightly elastic part that absorbs some of the initial ignition jolt.

An equivalent to the flywheel 48 (not shown) is to construct the inner race 4 with springs like the flywheel carried behind the engine of conventional vehicles. The inner race absorbs the ignition jolt.